

Research

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Nanosatellites Preparing for Launch

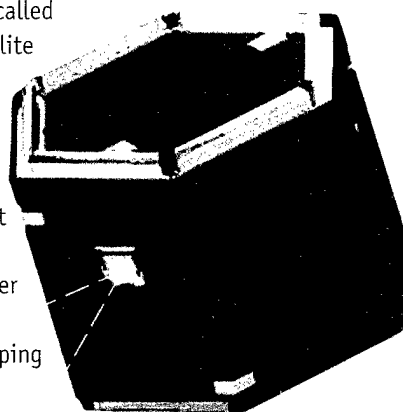
The Air Force will benefit from promising new technologies developed under a unique program involving universities, industry and government partners. The program, called the University Nanosatellite Program, will demonstrate miniature bus technologies, formation flying and distributed satellite capabilities that may enable more agile, less expensive and smaller satellites.

In addition to developing new technologies, the program, through its reliance on students, helps expose future scientists and engineers to the technological needs of the Air Force. More than 500 graduate and undergraduate students are expected to contribute to this three-year program.

The University Nanosatellite Program is jointly funded by AFOSR and the Defense Advanced Research Projects Agency. The universities formed partnerships with other universities and private industry.

AFRL is also playing an important role in this program.

The Space Vehicles Directorate of AFRL has been managing the program and also making facilities and expertise available to the universities for the design,



After delivery to AFRL in April 2001, the satellites are expected to be launched in November 2001 or shortly thereafter.

construction, testing, and integration phases. AFRL has been developing a deployment structure, and also working on integrating the nanosatellites, securing a launch, and providing such advanced microsatellite hardware as high efficiency solar cells and micropropulsion.

NASA Goddard has also teamed with the universities to provide approximately \$1.5 million funding to demonstrate such formation

flying technologies as advanced crosslink communication and navigation hardware and flight control algorithms.

More information on the program is available at www.nanosatellite.usu.edu

THE TECHNOLOGY

The program focuses on developing and understanding six technologies critical to satellite operations. The six technologies are:

- Formation flying
- Micro-propulsion
- Multifunctionality
- Miniaturized sensors
- Guidance and navigation
- Collaborative processing

The universities selected by DoD for this program and their alliances are:

THREE CORNER SAT:

- Arizona State University
- University of Colorado at Boulder
- New Mexico State University

EMERALD:

- Stanford University
- Santa Clara University

CONSTELLATION PATHFINDER:

- Boston University

SOLAR BLADE NANOSAT:

- Carnegie Mellon University

ION-F:

- Utah State University (USU Sat)
- Virginia Polytechnic Institute and State University (VTISMM)
- University of Washington (UW Nanosat)

RIGHT: Boston University Associate Provost for Research Carol Simpson (left), Sherri Godlin Stephen, graduate student at the Center for Space Physics, and Harlan Spence, associate professor of astronomy, holding an actual-size model of a nanosatellite designed by Spence and a team of investigators from Boston University's Center for Space Physics.

Photo: Kalman Zabarsky, Boston University Photo Services



University Nanosatellite Program Alliance Participa

THREE CORNER SAT CONSTELLATION

Participants: Arizona State University, University of Colorado and New Mexico State University

The proposed constellation of three identical nanosatellites will demonstrate stereo imaging, formation flying/cellular-phone communications, and innovative command and data handling.

Stereo imaging from space has several advantages over conventional imaging — more accurate data and greater coverage area.

A practical application of this technology is the imaging of clouds and thunderstorms, or convection. Conventional radar, while able to warn aircraft of the convection cells, is unable to determine the cell size in altitude. Because of this, air traffic often gets rerouted around the cell, while stereo imaging could route air traffic to areas where the cells are shallow.

Part of this research effort will also include a “virtual formation.” This formation is between satellites operating as a network, where targeting

and data acquisition are accomplished. Results are transmitted to the ground segment, and to the other satellites, via communications links without the need for strict physical proximity of the satellites. The communications links, which will carry the command and control data, will be from a commercial communications network in Low Earth Orbit. To accomplish this, the satellites will need to be “in range” — not necessarily close in proximity — and mutually known in order for each satellite to support its portion of the mission.

The Command and Data Handling System for the 3 Corner Sat constellation is designed as a distributed and simple system. As part of this distributed arrangement, each satellite uses a Satellite Processor Board that serves as its local controller, data interface, on-board memory, and processor. The three-satellite constellation can be controlled and managed by a processor on any of the three satellites via the communication links.

EMERALD

Participants:

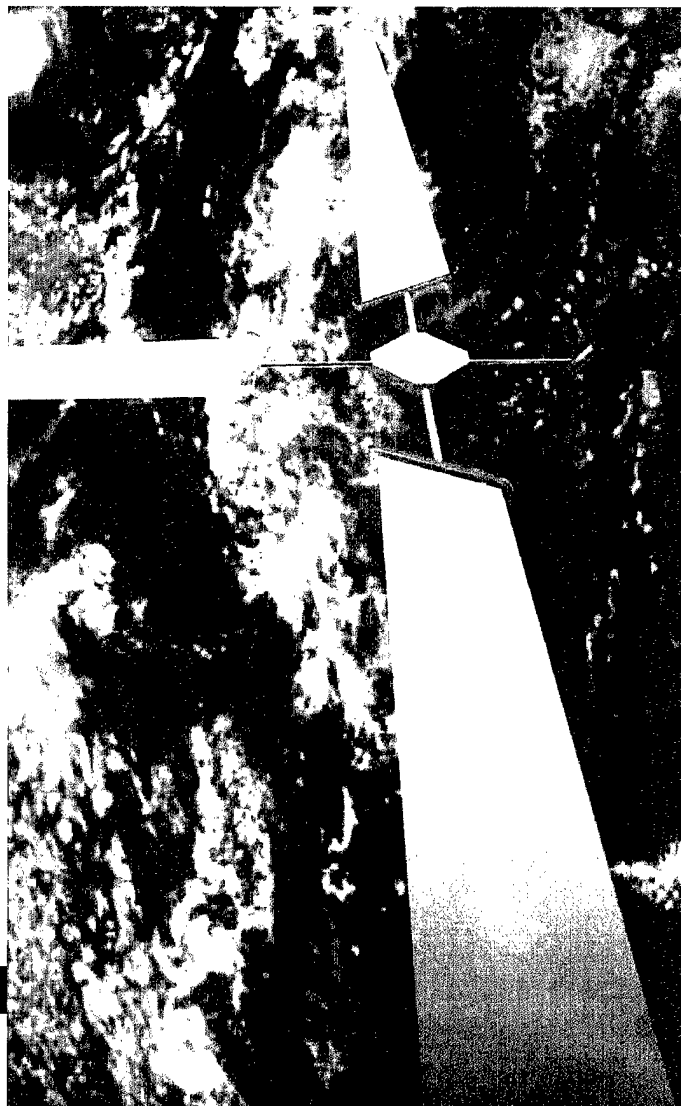
Stanford University and Santa Clara University

This low cost, two-satellite mission was formed for validation of formation flying technologies, which is a key technology needed in TechSat21.

The two EMERALD spacecraft will demonstrate several critical technologies for future formation flying missions:

- **GPS-based positioning.** For onboard orbit determination and relative navigation, a GPS receiver will be flown on each spacecraft, allowing relative position accuracy to within 6-15 feet.
- **Inter-satellite communication.** EMERALD plans to develop a simple inter-satellite communication link from the commercially available 19.2 kbs wireless radio modems.
- **Advanced colloid microthrusters.** Enables small scale position control. Microthrusters meet the stringent design criteria for the TechSat21 program.
- **Simple, passive position control devices.** A simple tether or flexible boom will maintain the satellites within a given distance. This tether may be cut later in the mission in order to demonstrate advanced formation flying capabilities.
- **Deployable panels** on both spacecraft will allow simple, low performance drag control.

BELOW: Artist rendering of the Solar Blade Solar Sail, part of the AFOSR/DARPA University Nanosatellite program at Carnegie Mellon (Illustration: Marion "Trey" Smith)



Students Play Key Roles in Developing New Technologies

CONSTELLATION PATHFINDER

Participant: Boston University

The objective of this program is to demonstrate the feasibility of fabricating and launching one to three, small, less than 1 kg (2.2 lbs) satellites that are capable of collecting and returning quality scientific and engineering data for one to four or more months. BU's objective has been to assess the feasibility of placing hundreds of satellites equipped with magnetometers, into dimensional picture of dynamic phenomena in geospace than has been possible previously.

The study's objectives are:

- Autonomous spin-stabilized nanosatellites
- Measure low-level DC magnetic fields in space
- Launch from "mother ship" that may also provide a central point for inter-satellite communication



As compared to typical satellite designs this mission is particularly stringent in terms of requiring low mass and low power. In view of the large numbers of satellites eventually involved, the design must address manufacturability — simplicity of fabrication, assembly and calibration. On the other hand, the large number of satellites also reduces the reliability requirements. Failure of a few satellites simply reduces the number of data points but it does not lead to mission failure.

SOLAR BLADE SAIL

Participant: Carnegie Mellon

As part of this program, Carnegie Mellon is working on developing and flying the first solar sail, a spacecraft which utilizes solar radiation pressure as its only means of propulsion and attitude control. The solar pressure will enable altitude changes, spin rate changes and orbital position changes.

The Solar Blade Heliogyro Nanosatellite resembles a Dutch windmill and employs control akin to a helicopter. The core of the nanosatellite

contains the computer, communications system and attitude determination hardware. Four bending struts are attached to the core and solar cells cover the top surface. The blades attach to the struts through individual actuators. The design and materials are tear resistant. The spacecraft weighs less than 10 pounds, and, when stowed, is about the size of a fire extinguisher.

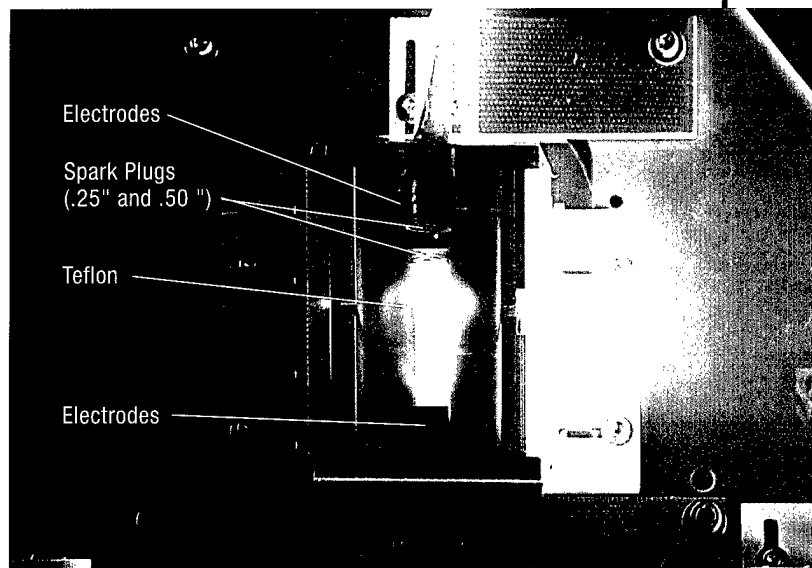
ION-F (Ionospheric Observation Nanosatellite Formation)

Participants: Utah State, University of Washington and Virginia Polytechnic

Three nanosatellites, one from each university, will weigh about 22 lbs. each.

The goals of the ION-F alliance program are:

- Basic research mission of investigating global ionospheric effects which affect the performance of space based radars, and other distributed satellite measurements.
- Formation flying and local communication in a constellation, including upgrade from a three nanosatellite constellation to four nanosatellites.
- Baseline new technologies including micro-thrusters, attitude control, advanced tether system, and an Internet based operations center.
- Internet control of a distributed space system



ABOVE: Micro-Pulsed Plasma Thruster firing during tests. The micro-PPT was designed in collaboration with Primex Aerospace Company for small satellites.

LEFT: As part of the Three Corner Satellite Constellation program, students at Arizona State University work on an actual model of the nanosatellite system, which will function as a network of three.

The DoD Engineer and Scientists Exchange Program, or ESEP, supports science and technology through international cooperation in military research, development, and acquisition through the exchange of defense scientists and engineers. ESEP provides on-site assignments for U.S. military and civilian scientists and engineers in foreign government organizations and reciprocal assignments of foreign scientists and engineers in U.S. government organizations. ESEP supports current USAF science and technology requirements by seeking specific foreign technologies. It provides insight into the technology and project management techniques of foreign laboratories and centers and opens areas of possible technical cooperation.

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Description of Work:

Research is geared towards developing models, and/or to improve existing models for simulating propellant sprays in high-pressure, liquid propellant combustion chambers. In particular, current topics of research include modeling of secondary atomization of liquid drops, that is, the breakup of drops due to aerodynamic forces, and combustion under supercritical conditions. To validate the numerical models, simulations are compared to experimental results provided by a cryogenic test cell located at ONERA's Palaiseau research center. This research will be used in the development of rocket engines.

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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